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ANTENNAS ARRAY CALIBRATION ARRANGEMENT AND METHOD

Field of the invention

The invention relates to an apparatus and a method for cont-
rolling transmission and/or reception of signals in a radio
communication system, especially for application in base sta-
tions of mobile radio communications systems.

Background of the invention

In radio communications systems, signals are exchanged be-
tween radio terminals and base stations via a so called radio
interface or air interface. Radio terminals are in general
mobile or stationary user terminals (UE - user equipments),
whereas base stations (NB - Node B) are access stations asso-
ciated with a land based communication network. Examples of
known radio communication systems are second generation digi-
tal mobile radio communications systems like GSM (Global Sys-
tem for Mobile Communication) based on TDMA (Time Division
Multiple Access) and providing data rates up to 100 kbit/s,
and third generation digital mobile radio communications sys-
tems like UMTS (Universal Mobile Telecommunication System)
based on CDMA (Code Division Multiple Access) with data rates
up to 2 Mbit/s.

Antenna arrays can be used in any type of system that trans-
mits and/or receives radio frequency signals using one or a
plurality of antennas. The use of antenna arrays in above de-
scribed systems provides for antenna performance improvements
over the use of a single element antenna, including improved
directionality, signal to noise ratio and interference rejec

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tion for received signals, as well as improved directional-
ity, security, and reduced power requirements for transmitted
signals. Antenna arrays can be used for signal reception
only, for signal transmission only, or for both signal recep-
5   tion and transmission. Most antenna array systems consist of
an antenna array and a signal processor that processes the
signals going to and coming from individual array elements.

Thus, an antenna array is composed of a number of so called
10   antenna elements, each connected to a radio frequency (RF)
transceiver (transmitter/receiver). In reception mode, the
receivers obtain RF signals from each antenna element and ap-
ply a down conversion of the received signals to base band
signals. In the base band, demodulated signals are then com-
15   pared with each other in amplitude and phase. The information
on the direction of arrival (DOA) of the incoming signal,
i.e. the direction of the transmitting station, is contained
in the relationship between the received signals. In trans-
mission mode, this information is subsequently used for beam-
20   forming (BF) in the direction of the received signal by cor-
rectly weighting base band signals for the different trans-
mitters connected to the antenna elements.

The procedure described above can only be realised with a
25   certain accuracy if the characteristics of the individual
transmitters and receivers are known, so that these charac-
teristics can be taken into account for the DOA and BF algo-
rithms. To be precise, transfer functions (in amplitude and
phase) from antenna elements to the base band outputs of the
30   receivers as well as transfer functions from the base band
inputs of the transmitters to the antenna elements must be
known. During operation these transfer functions are subject
to parameter variations (drift) of active and passive ele

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ments in the transceivers and cables. Therefore, transfer
functions have to be continuously or at least periodically
determined during operation of the transceivers.

5   Two different approaches of calibration procedures are known
in the art. According to a first procedure, a known signal is
fed to a test antenna (calibration antenna) which is arranged
close to or as part of the antenna array (known from prior
art document US-A-6236839) or is separated from the antenna
10   array (known from prior art document US-A-5546090). The base
band signals carry information about the transfer functions
of the individual receiver paths, which can then be compared
and adjusted. This procedure is called RX calibration.

15   According to a second procedure, known signals are fed to the
individual antenna elements and received by a test antenna.
The test antenna could thereby be located as described above.
The received signals carry the information about the individ-
ual transfer functions of the transmitter paths, which are
20   subsequently compared and adjusted. This procedure is called
TX calibration.

Both calibration procedures can be realised either simultane-
ously, which is a preferred solution in systems using fre-
25   quency division duplex (FDD), or consecutively as preferred
in systems using time division duplex (TDD).

Configurations enabling the above described procedures are
shown in FIG 2 and 3. According to these configurations, a
30   calibration antenna is connected by means of a duplexer or
switch to calibration transmitter (TXc) and receiver (RXc)
circuits operating in the radio frequency range. Signals
from/to the calibration antenna are processed in a calibra

tion processor operating in the base band. The calibraton
processor is connected to a beamforming processor that proc-
esses signals from/to the individual antenna elements
(#1...#n) of an antenna array of e.g. a base station. Coeffi-
5   cients representing the determined variations are stored in
lookup tables.

In a RX calibration procedure (FIG 2, the signal flow is pre-
sented by broken lines), the calibration processor initiates
10   the transmission of test signals from the calibration antenna
over the air interface to the individual antenna elements of
the antenna array. The received test signals are then fed
back to the calibration processor by means of the beamforming
processor. Within the calibration processor, transfer func-
15   tions of the individual receiver paths are determined and
evaluated and stored in a lookup table in order to be taken
into account for normal operation of determining directions
of arrival.

20   In a TX calibration procedure (FIG 3, the signal flow is pre-
sented by broken lines), the calibration processor initiates
the transmission of test signals from each of the antenna
elements which are received by the calibration antenna. The
received signals containing information about the transfer
25   functions of the individual transmitter paths are then evalu-
ated in the calibration processor and stored in a lookup ta-
ble in order to be taken into account for the normal opera-
tion of beamforming.

30   The described procedures suffer from the fact that special-
ised calibration means have to be integrated within each base
station, thereby causing additional costs and space require-
ments.

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It is therefore an object of the invention to provide cali-
bration arrangements which do no suffer from the above stated
disadvantages. This object is addressed by the arrangement
5   and method according to the features of the independent
claims.

Statement of the invention

10   According to a first and second aspect of the invention, an
arrangement and a method for controlling transmission and/or
reception of signals in a radio communication system is pro-
vided. The arrangement thereby consists of transceiving means
and antenna elements, wherein at least one of the transceiv-
15   ing means is additionally connected to a calibration antenna.
The arrangement furthermore consists of a calibration proces-
sor for determining variations of the test signals in the
transceiving means, and a beamforming processor for taking
into account the determined variations for beamforming and/or
20   determination of direction of arrival of respectively trans-
mitted and received radio signals by the antenna elements.

The usage of transceiving means normally used for transmis-
sion and reception of radio signals to/from other radio sta-
25   tions for transmitting and/or receiving test signals via a
calibration antenna in calibration procedures allow the sav-
ing of additional space and costs required for separate cali-
bration transceiving means used in the prior art.

30   Further aspects of the invention are disclosed in the follow-
ing description of the figures.

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Brief description of the figures

The invention may be understood more readily, and various
other aspects and features of the invention may become appa-
5   rent from consideration of the following description and the
figures as shown in the accompanying drawing sheets, wherein:

       FIG 1   shows a block diagram of a radio communication net-
10   work,
       FIG 2   Shows a signal flow for RX calibration in an arrange-
                ment known in the art,
       FIG 3   shows a further signal flow for TX calibration in an
                arrangement known in the art,
15   FIG 4   shows an arrangement according to the invention in a
                TX calibration procedure,
       FIG 5   shows the arrangement according to the invention in a
                RX calibration procedure,
       FIG 6   shows the structure of a time frame of a TDD radio
20   communication system,
       FIG 7   shows the arrangement according to the invention
                with additional amplifiers arranged close to the an-
                tenna elements,
       FIG 8   shows the arrangement according to the invention with
25   a plurality of calibration processors for simultane-
                ous calibration in different radio frequency bands,
                and
       FIG 9   shows the arrangement of FIG 8 with an optical link
                connection between multiplexer means.
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Detailed description of the invention

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FIG 1 shows the basic structure of a mobile radio communications system, e.g. a GSM system. The system consists of a central mobile switching center MSC which is connected to the public switched telephone network PSTN and other MSCs. Con-

5   nected to a MSC are a plurality of base station controllers BSC, which inter alia coordinate the sharing of radio resources provided by base stations BTS (Base Transceiver Station). Base stations BTS transmit in downlink DL and receive in uplink UL signals respectively to or from user equipments

10   UE situated within an area covered by the base station BTS. In FIG 1 the base station BTS comprises an antenna array A consisting of a number of antenna elements. The antenna array, which depending on the configuration is sometimes also called smart antenna, is used for beamforming of signals

15   transmitted to individual user equipments in order to reduce interference caused to signal transmissions of parallel connections to other user equipments.

An arrangement according to the invention as shown in FIG 4

20   and 5 is based on the structure of FIG 2 and 3 described above. In contrast to arrangements known in the art, one of the transceiving means TX,RX is not only connected to one of the individual antenna elements #1...#n, but also to a calibration antenna via a switch S. In a calibration procedure,

25   test signals are switched to/from the calibration antenna, whereas in normal operation, signals are transmitted and/or received via the antenna element connected to the transceiving means. The switch is realised in the radio frequency in any possible way known to the expert.

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In the following, RX and TX calibration procedures using arrangements according to the invention are described with reference to FIG 4 to 9. These procedures can be realised con

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tinually or periodically during operation of the transceivers.

In a RX calibration procedure, i.e. calibration of the recei-
5   ving paths of the transceivers, the calibration processor or
an individual source generates test signals in the base band,
which are converted into radio frequency band signals by a
transmitter TX (in FIG 4 the transmitter on the right hand
side) and fed to the calibration antenna via a switch S. Af-
10   ter transmission over the air interface, the test signals are
received by the individual antenna elements #1...#n and down-
converted in the individual receivers RX into base band sig-
nals again. The beamforming processor connected to the
transceiving means provides the received signals that contain
15   information about transfer functions of the individual signal
paths to the calibration processor, in which the differences
in receiver characteristics are determined. Information about
the determined differences are then stored in a RX coeffi-
cient lookup table and fed back to the beamforming processor
20   in order to be taken into account for normal operation of de-
termining directions of arrival of radio signals from user
equipments in communication with the base station. As coeffi-
cients, e.g. maxima of phase and amplitude differences of
coupling coefficients are determined by the calibration proc-
25   essor.

It can be seen from FIG 4 that the arrangement according to
the invention makes simultaneous use of the transmitting as
well as the receiving path of the transceiver on the right
30   hand side.

In a TX calibration procedure, i.e. the calibration of the
transmitting paths of the transceivers, the calibration pro

cessor or an individual source generates base band test sig-
nals that are fed to the transmitting means TX of the trans-
ceivers via the beamforming processor. The calibration proc-
essor is thereby realised within the beamforming processor or
5   as a separated unit that is connected to the beamforming
processor.

The test signals are upconverted into radio frequency band
signals by the transmitting means TX and fed to the individ-
10   ual antenna elements #1...#n. After transmission over the air
interface, the test signals are received by the calibration
antenna, fed to the receiver RX via a switch S and downcon-
verted in the receiver RX again into base band signals. From
these received test signals, the calibration processor deter-
15   mines differences in transmitter characteristics and stores
information about the determined differences in a TX coeffi-
cient lookup table in order to be taken into account for nor-
mal operation of beamforming of radio signals to user equip-
ments by the beamforming processor. As coefficients e.g.
20   maxima of phase and amplitude differences of coupling coeffi-
cients are determined by the calibration processor.

FIG 6 shows the structure of a time frame of a TDD (Time Di-
vision Duplex) system known from the third generation UMTS
25   TDD-LCR (TDD-Low Chip Rate) standard and the chinese TD-SCDMA
standard. The time frame consists of seven timeslots
TS0...TS6 which are allocated either in uplink (↑), i.e. from
the user equipments to the base station, or in downlink (↓),
i.e. from the base station to the user equipments. After the
30   first timeslot TS0, which according to the standard is always
used for downlink transmission, a first switching point is
provided with a special downlink pilot timeslot DwPTS, uplink
pilot timeslot UpPTS and an extended guard period gap in be

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tween. According to the invention, this extended guard period
gap is partly or entirely used for the transmission of test
signals (in a so called cal frame) for RX and TX calibration.
As an advantage, the usage of the extended guard period for
5   the transmission and reception of calibration test signals
reduces neither the overall transmission capacity of the time
frame nor the performance of the system.

A further arrangement according to the invention is disclosed
10 in FIG 7. In this case, power amplifiers PA, LNA operating in
the radio frequency range are arranged close to the antenna
elements #1...#n and normally mounted on a tower remote from
the base station. These power amplifiers are often called
tower mounted amplifiers. The connection between the remote
15 power amplifiers and the transceivers located in the base
station is realised e.g. by individual coaxial cables as
shown in FIG 7. Accordingly, also the calibration antenna ar-
ranged close to the antenna elements is connected to one of
the transceivers via a coaxial cable. It is not necessary to
20 provide separate power amplifiers for the transmission and
reception of test signals since the required transmission
power is restricted and could be easily provided by the
transmitter TX in the transceiving means. Moreover, the loss
of the coaxial cables does not have any negative influence on
25 the measurements in general and e.g. noise figures of the re-
ceiver. In this configuration, transmitting and receiving
paths variations taking into account all receiving and trans-
mitting means can be determined in the calibration processor.

30 Because the transceiving means TX, RX only operate in a sin-
gle frequency band at a time, the TX calibration procedure is
configured in that the calibration processor controls the
transmitting means TX in that only one transmitting mean TX

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transmits test signals to the calibration antenna at a time
in order to separate the received signals of the individual
transmitting means TX in time. With reference to FIG 6, e.g.
different transmitting means TX transmit consecutively test
5   signals in the transmission gap.

In an RX calibration procedure, test signals are transmitted
from the calibration antenna in a certain frequency band, re-
ceived by all receiving means RX at the same time and ana-
10   lysed concurrently in the calibration processor. From one
time frame to another, test signals are transmitted in dif-
ferent frequency bands in order to calibrate the transmission
and/or reception paths for all carriers used.

15   Since the realisation of TX and RX calibration procedures for
a plurality of frequency bands would require the usage of a
large number of consecutive time frames, FIG 8 discloses a
further implementation alternative. Instead of just one cali-
bration processor and corresponding lookup tables for storing
20   determined coefficients, a number m of base band signal proc-
essing units are realised and connected to the transceiving
means TX, RX e.g. via a base band multiplexer. Preferably,
the number of base band signal processing units, comprising
inter alia beamforming and calibration processors as well as
25   lookup tables, is chosen according to the number of frequency
bands in which the multicarrier transceivers operate.

The usage of a plurality of base band signal processing units
enables the application of simultaneous calibration proce-
30   dures in a number of frequency bands. This could be realised
in that the transceivers TX, RX process m carriers simultane-
ously and the corresponding base band signals are multiplexed
to different signal processing units, each operating for a

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particular frequency band. The signal processing units then
realise a calibration for the individual frequency bands of
the corresponding carriers.

5   In a TX calibration procedure, test signals in different fre-
quency bands are transmitted concurrently by a number or all
transceivers, e.g. dependent on the number of base band sig-
nal processing units. These test signals are received by the
calibration antenna and receiving path of one of the trans-
10   ceivers, and multiplexed to the individual processing units
for the different frequency bands. From one calibration pro-
cedure to another, the individual transceivers use different
frequencies for the transmission of the test signal, so that
characteristics of each transmitting path can be analysed for
15   each frequency band in a relatively short time.

In a RX calibration procedure, test signals are transmitted
via the calibration antenna and received by the individual
receiving paths of the transceivers. For each frequency band
20   or carrier used for transmission of test signals, one of the
calibration processors determines individual variations of
the characteristics of the receiving paths.

According to another alternative implementation of the inven-
25   tive arrangement shown in FIG 9, the base band signal proc-
essing units are connected to n remote transceivers via an
optical link. This optical link arrangement could equally be
used instead of coaxial cables described with reference to
FIG 7. In the case of FIG 9, the base band multiplexer de-
30   scribed with reference to FIG 8 is divided into a base band
transceiver multiplexer arranged close to the tower mounted
transceivers and antenna elements, and a base band channel
multiplexer arranged close to the base band signal processing

units, preferably in the base station. The optical link is
thereby realised by optical transceivers connected to the
multiplexers and one or a plurality of optical cables. Advan-
tage of the use of optical links instead of coaxial cables

5   are e.g. that a smaller number of cables have to be installed
for the connection between the base station and the remote,
tower mounted transceivers and antenna elements, and that
less insertion losses occur.

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Claims

1. Arrangement for controlling transmission and/or reception
of signals in a radio communications system, comprising
5   transceiving means (TX,RX) each connected to one element of
an array of antenna elements (#1...#n), wherein at least one
of said transceiving means (TX,RX) is additionally connected
to a calibration antenna for transmitting and/or receiving
test signals to and/or from said antenna elements (#1...#n),
10   at least one calibration processor for determining variations
of said test signals in said transceiving means (TX,RX), and
a beamforming processor for taking into account the determi-
ned variations for beamforming and/or determination of direc-
tion of arrival of respectively transmitted and received ra-
15   dio signals by said antenna elements (#1...#n).

2. Arrangement according to claim 1, wherein
a transmission gap in a time frame of a TDD system is used
for the transmission of said test signals for determining
20   variations in the calibration processor.

3. Arrangement according to claim 1 or 2, wherein
in the said at least one transceiving means (TX,RX) connected
to the calibration antenna test signals are switched via a
25   switch (S) to the calibration antenna in a calibration proc-
ess.

4. Arrangement according to one of the preceding claims,
wherein
30   said calibration processor is realised within the beamforming
processor.

5. Arrangement according to one of the preceding claims, com-
prising

at least one lookup table for storing the determined varia-
tions of the individual transceiving means (TX,RX).

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6. Arrangement according to one of the preceding claims,
wherein

at least two calibration processors, each determining varia-
tions for a different radio frequency, are connected to said

10   transceiving means (TX,RX) via a base band multiplexer.

7. Base station (BS) of a radio communication system, com-
prising an arrangement according to one of the preceding
claim.

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8. Method for controlling transmission and/or reception of
signals in a radio communication apparatus (BS), the radio
communication apparatus (BS) comprising transceiving means
(TX,RX) each connected to one element of an array of antenna

20   elements (#1...#n), at least one of the transceiving means
(TX,RX) being additionally connected to a calibration an-
tenna, wherein

in a receiver calibration procedure, test signals are gener-
ated, fed to the at least one transceiving means (TX,RX) con-

25   nected to the calibration antenna, transmitted via the cali-
bration antenna and received by said antenna elements
(#1...#n) and corresponding transceiving means (TX,RX),
and/or

in a transmitter calibration procedure, test signals are gen-

30   erated, fed to the transceiving means (TX,RX), transmitted
via said antenna elements (#1...#n), and received by said
calibration antenna and said one of the transceiving means
(TX,RX),

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variations of the test signals in the transceiving means
(TX,RX) are determined in at least one calibration processor,
and

the determined variations are taken into account for beamfor-
5   ming and/or determination of direction of arrival of respec-
tively transmitted and received radio signals by said antenna
elements (#1...#n).

9. Method according to claim 8, wherein
10   variations of the test signals are determined consecutively
for different radio frequencies.

10. Method according to claim 8 or 9, wherein
variations of the test signals are determined concurrently
15   for different radio frequencies, thereby using individual
calibration processors for the different radio frequencies.

11. Method according to one of the preceding claims 8 to 10,
wherein
20   transfer functions of the transmitting and/or receiving paths
are determined in the calibration processor.

12. Method according to one of the preceding claims 8 to 11,
wherein
25   the calibration processor determines a maximum of a phase and
amplitude difference of a coupling coefficient.

13. Method for controlling transmission and/or reception of
signals in a radio communication apparatus (BS), the radio
30   communication apparatus (BS) comprising transceiving means
(TX,RX) each connected to one of an array of antenna elements
(#1...#n) and calibration transceiving means connected to a
calibration antenna, wherein

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in a receiver calibration procedure, test signals are generated, fed to the calibration antenna, transmitted via the calibration antenna and received by said antenna elements (#1...#n) and corresponding transceiving means (TX,RX),

5   and/or in a transmitter calibration procedure, test signals are generated, fed to the transceiving means (TX,RX), transmitted via said antenna elements (#1...#n), and received by said calibration antenna and said calibration transceiving means (TX,RX), wherein a transmission gap in a time frame is

10 used for the transmission and reception of said test signals, variations of the test signals in the transceiving means (TX,RX) are determined in at least one calibration processor, and
the determined variations are taken into account for beamfor-

15 ming and/or determination of direction of arrival of respectively transmitted and received radio signals by said antenna elements (#1...#n).